# HUMAN ENGINEERING DESIGN CRITERIA STUDY

## QUARTERLY PROGRESS REPORT NUMBER TWO

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WORK COMPLETED

During the second quarterly reporting period the following tasks were completed:

Fourth Month

1. Literature dealing with operational environment (illumination, noise, temperature and vibration) continued to be sought and acquired. Fourteen new documents were requested and at the end of the month 12 had been received. The literature of lighting contains much conflict which does not seem to be resolved by research. This is not the case with glare, however, where much more agreement exists.
2. Literature dealing with safety was sought and ordered. Sixteen documents were requested and at the end of the month eight were received. Some overlap with the literature of operational environment was expected and did in fact occur.
3. Man's Capability--Weight Lifting. The literature dealing with this topic was not plentiful as only about eight good publications had been found. Most of these dealt with a relatively static situation involving a vertical lift. It was hoped that more literature would be found to deal with certain dynamic variables such as weight carrying over a distance and weight lifting at different angles of arms and leg flexion.

4. Control & Display. There was a myriad of literature dealing with this broad area. Many publications were ordered or requested through the library solely on the basis of their titles in hopes that their contents would be pertinent and useful. A casual perusal of the publications acquired so far indicated that most of them were useful although there were certain inconsistencies in findings.

   The following specific areas dealing with control and display were found to have satisfactory substantiating data: control motion stereotype, control design, control separability, and control actuation. A new list of control and display references accompanied the fourth monthly progress report.

5. Decision Making. Most of the literature found was of a theoretical nature which was not judged to be useful. It was hoped that publications yielding more concrete data would be found. Literature search in this area was continuing.

6. Nine more responses to the letter of solicitation were received. This raised the response percentage to 33% with a total of 36 documents actually in hand.

7. The NASA Contract Monitor (MSFC-P&VE) and a representative of NASA MSFC-Astrionics visited both the Huntington Beach and Long Beach facilities to confer with the staff

employed in specific situations. In general, they are unsupported by empirical data but do have rather strong face validity. Considerable overlap is observed with the literature of clothing when considering protective garments.

3. Much of the literature acquired in the area of clothing proved to be of limited utility to this project since it dealt for the most part with clothing used in high altitude flying or space travel.
4. Newly acquired publications in the area of Maintainability were examined and integrated into the draft of maintainability chapter.
5. Letters of inquiry were sent to researchers active in the field of dynamic anthropometry. Anthropometry items which seem appropriate for the workspace chapter were set aside.

WORK UNDERWAY

During the second quarterly reporting period the following work was underway:

Fourth Month

1. Print-out cards from the computer search continued to be examined as emphasis in the work moved from one topic area to another in keeping with the Milestone Schedule.
2. Although the search for literature continued, more effort was being devoted to reviewing and abstracting

of the project. The possible need for further clarification of the breadth and depth of each of the nine major areas of the study was discussed. Recommendations regarding this discussion were anticipated from MSFC personnel. Another topic of discussion was the need for assistance in obtaining materials from some contractors.

Fifth Month

1. The accumulation and review of literature for the anthropometry bibliography was continued. Literature that was not immediately available was ordered. Two letters were sent to workers in the field of dynamic anthropometry seeking their more recent findings and leads to other workers and studies. A list of the addresses accompanied the fifth monthly progress report.
2. The search for literature in weight-lift capacity (Man's Capability) was approximately 75% complete. When literature on order is received, the search will be considered complete. In general, data are quite ambiguous since too many variables are involved.
3. The search for literature in decision processes yielded an additional fifteen references. Most of these were theoretical in nature.
4. The search for literature dealing with safety continued. Seven titles were obtained during the month and another 18 were on order. Much of the safety literature obtained overlapped with the areas of operational environment and

clothing. The literature tended to be surveys of practices and accident reports with suggested remedies.

5. Literature on clothing was also sought. This literature dealt not only with garments themselves but with heat, cold and moisture resistant textiles. Garment dimensions were treated in some instances. Six titles were in hand while 15 more were on order.
6. Back-orders of literature on operational environment continued to arrive. Ten publications were received while an additional 44 remained on order. The literature received was not concentrated in any one area and included illumination, noise, temperature and vibration.
7. One response to the letters of solicitation was received during the month leaving the response percentage virtually unchanged.

Sixth Month

1. Previously ordered literature on operational environment continued to arrive. Vibration and temperature-humidity were represented but the bulk of the materials dealt with illumination and noise. More agreement on the effects of various noise levels was encountered than was true in the literature treating lighting requirements. Opinions and data interpretations of researchers in the latter area were often in direct conflict.
2. The search for safety literature continued. Materials received are largely statements of procedures to be

materials that were already in-hand. These abstracts were being accumulated until there were a sufficient number to begin integrating them into a rough draft.

3. Responses to the letter of solicitation continued to be received. In some instances the responses included names of persons believed to be sources of pertinent materials. These persons were then contacted by letter. A list of names received in October accompanied the fourth monthly progress report.
4. Some first efforts to clarify and describe the content and limits of the major areas had begun. It was not expected that this would achieve fruition until conferring further with MSFC personnel, however.

Fifth Month

1. Print-out cards from the computer search continued to be examined for leads in the literature of all the areas. It was expected that this activity would terminate during the month of December.
2. Literature was being acquired and reviewed in all of the areas. If pertinent, it was abstracted and added to the appropriate bibliography. Time spent in locating and obtaining literature still exceeded time spent in reviewing and abstracting it, however.
3. More effort was being given to producing a written rationale for each area as well as a description of its contents. Drafts of this work were expected to be included in the second quarterly report.

4. Effort was being resumed on controls and displays. This work had ceased temporarily while effort was expended on acquiring literature on man's capability and decision processes.

Sixth Month

1. The literature review, including acquisition efforts, is continuing in all of the major areas. As in the past the controls and displays area remains the richest in publications in hand and on order.
2. Abstracts of pertinent literature continue to be prepared and/or collected in reproducible form. It is anticipated that copies of these abstracts will accompany the next monthly progress report.
3. Bibliography of material pertinent to the chapter on man's capability is being accumulated preparatory to the initial investigation of that literature.
4. Brief descriptions of the content areas contained in each section are being drafted. Some limited amount of rationale is being included as well. First drafts of this work accompany this report.

WORK/PROBLEMS ANTICIPATED

Fourth Month

As mentioned earlier, additional attention is being given to the descriptions of each of the nine major areas of the study's organization. Achieving the breadth and depth

necessary for comprehensive treatments of these areas will be difficult because of the great quantities of literature to be reviewed by a limited number of personnel. Further, as much, or more, time is required to locate material as is required to review it for pertinency and abstract it. Decisions, therefore, will probably have to be made in the near future regarding the limits or cut-off points for the various areas.

Fifth Month

As described in the two preceding sections of this report, steady progress is being made in locating, obtaining and abstracting pertinent literature in all of the various areas. The time spent in acquiring and reviewing literature (some of which is found to be of little value when examined closely) remains a problem because of the very bulk of literature and the limited number of personnel.

Sixth Month

Progress has been steady in locating, obtaining and reviewing literature in all areas. Information collected is more abundant in some areas than others. This is due to a paucity of specific pertinent literature in some cases but more often reflects the need for additional help in the literature search. It is hoped that a meeting, between NASA personnel and the Project Staff can be arranged soon

In order to resolve this problem and to determine the implementation of the Adequacy Scale as well.

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Attachment: 4 (As Noted)

FIRST DRAFT OF CHAPTER INTRODUCTIONS

The following pages contain the first draft introductions for the various chapters of the document to be produced. They are purposely brief and hopefully clear since they are intended for: (1) human factors specialists who are already steeped in the backgrounds and rationales of each area, and (2) design engineers who have greater need for specific information than for historical/philosophical backgrounds of human engineering.

NOTE: Introductions for Clothing, Controls and Displays, Decision Processes, Presentation of Information, and Workspace Criteria will accompany the next monthly progress report.

# SAFETY

Safety considerations permeate almost all of man's industrial activities and in the broadest sense they are present in all sections of this document. The chapters on Clothing, Maintenance and Operational Environment, in particular, contain many examples of this widespread permeation. This chapter will deal more specifically with those practices, procedures and devices which are employed to protect both personnel and equipment from accidents and injury.

The basic philosophy of a safety program is one of accident anticipation and prevention. This involves a careful assessment of the hazards inherent in given situations and the available means of negating or reducing them. The design engineer therefore needs to incorporate as many of these means into his design as is possible and where trade-offs are unavoidable, procedures which minimize hazards should be developed concurrently with the equipment design itself.

Some of the safety measures contained in this chapter are supported only by their face validity while others have empirical support from accident investigations. The subject matter ranges from the complex safety procedures--including special safety equipment--to the simpler remedies of providing railings for work areas at high elevations.

# ANTHROPOMETRY

Anthropometry deals with the measurement of the human body; the field is divided into a number of subspecialities. For this document the comparative studies will be ignored unless they provide data on United States populations deemed similar to the population of space vehicle crews and ground support technicians.

The bulk of readily available data falls in the class of static anthropometry. These are measurements of the standing or seated subjects. Many of the dimensions obtained are of low utility to the design engineer. An attempt will be made to present those dimensions relevant to the anticipated design problems of launch vehicles and ground support equipment.

There are relatively few studies of the human in action. As Rowland so aptly stated, when the body moves, limbs, tissues, and garments thrash, flail, flap and flutter complicating the problems of the designer. Measurements obtained under dynamic conditions tend to better fit the needs of designers than extrapolations from static measurements as they include the actual range of movements (often non-linear) rather than the expected linear movements.

Certain techniques of measurement may introduce bias into the measurements. This is particularly true of photographic measurements which may introduce considerable distortion by parallax.

# MAN'S CAPABILITY

The inclusion of man in a system places a requirement on the designer to provide inputs to the man in such a form as is readily perceived. Likewise, control and input devices should require responses that man is easily capable of, in terms not only of physical and cognitive processes but also latency of response and frequency of responding.

The chapter will cover the literature regarding the sensory discriminational acilities of man in terms of thresholds, just noticeable differences (jnd), and optimal ranges of stimulation. Special emphasis will be placed on the visual and auditory modalities inasmuch as these are the most frequently employed. The capabilities of man to lift, pull and otherwise manipulate objects will be covered.

Just as man is capable of being overtaxed in a physical sense, so also can he be overloaded in cognitive functions. Data processing ability varies with conditions--rate of presentation, number of categories, and discriminatability of the categories.

## Maintainability Philosophy and Rationale

The term maintainability seems to be somewhat like virtue in that it means different things to different people. There are certain areas of agreement such as a close relationship to reliability and a major cost factor in systems operations.

Chapanis and Cook (1963) offer the following definition:

> "Maintainability is the degree of facility with which an equipment or system is capable of being retained in, or restored to, serviceable operation. It is a function of parts accessibility; internal configuration; use and repair environment; and the time, tools, and training required to effect maintenance." (p. 367)

The goals of maintainability seem to be two-fold (a) to increase the amount of time a system is available for its intended function, (b) to affect reductions in the cost of systems operations. In essence, goal (a) infers the increase of reliability with the implication that improved component and sub-assembly reliabilities will reduce the need for maintainability considerations. Goal (b) likewise promises lowered operational costs as reliability is increased.

It can be argued that maintainability is primarily a synonym for repairability. However, the maintenance of equipment involves more than the repair of faulty components. The functions of testing, preventative maintenance and trouble-shooting are also

included in maintainability. Factors which promote repairability may also make for ease of preventative maintenance of the unit but may not improve testing and trouble-shooting tasks. Thus the designer must consider both aspects in determining the final blend of components and configurations.

Designing for maintainability, like design for any other attribute, is most successful when criteria are incorporated in the earliest stages of planning. To successfully design for maintainability it is necessary to have information on the following:

1. Operational equipment similar to the proposed design. Listings of maintenance features incorporated and maintenance problems arising during usage are especially needed.

2. Familiarity with the function of the equipment in the entire system as well as its specific location in terms of access, structural restrictions and environmental conditions.

3. Determine what equipment being used to test and service related equipment is suitable, with or without adaptation to the current design.

4. Find out what types of maintenance men will be available for the task. Prepare lists of the skills they must possess.

5. The work and storage areas that can be used for the equipment and support gear. Also what supply facilities are available to provide spare parts.

6. The level of maintenance that will be performed in location, in shop, and rear echelon repair.

The ever growing body of maintainability criteria, guidelines and rules has been developed largely through insight, suggestions of maintenance personnel, and study of failure reports of existing systems. Few systematic studies of variables influencing maintainability have been conducted (Rigney & Hoffman, 1962) and the bulk of those have tested either training procedures or a specialized piece of testing equipment.

Most maintainability criteria seem to have been developed to cope with expected or existing problems. The geneology of such criteria is usually obscured and impossible to trace. The true value of these rules can not readily be ascertained, but all do have high face validity in that they seem highly reasonable solutions to the problem.

# OPERATIONAL ENVIRONMENT

The performance of an operator of a machine is affected not only by the design of the machine itself, but also by the environmental situation in which the operator must work. Certain conditions are detrimental to human performance while others tend to optimize it. The importance of these conditions--whether they be generated by the system or are independent of it--has been noted repeatedly. Most recently McFarland and Teichner (1960) stated:

> The environment in which a man operates a machine must be included as a consideration in the design of the man-machine system because the environmental conditions can seriously affect his performance. Indeed, machines have often failed to fulfill their missions, not because they were poorly designed or badly constructed, but because they demanded more of the operator than was humanly possible considering the environment. (p. 411)

Early recognition of negative environmental conditions by the designer is necessary so that counter measures can be included in the design or operating procedures. Major conditions to be considered are temperature and humidity, noise, vibration and illumination.

In addition to conditions created by or necessary for the machine itself, consideration should be given to conditions already in existance at the actual place of operation, e.g., temperature and humidity of the locale.

Essentially this section of the document deals with obtaining an optimal, uniform performance from man by attending to his requirements and limitations.

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